January 19, 2022

PLANETARY SCALED DIRECT AIR CARBON CAPTURE

(FINAL UPDATE – JANUARY 2022)

PTJ North

INTRODUCTION

"Conventional infrastructure funding can't work for planetary scale projects."

This final update of the author's original DACC (Direct Air Carbon Capture) conceptual design seeks to clarify several important points for this summary topic report which he originally published in 2019. It does highlight a much-simplified process flow diagram that he has not previously published.

Ownership of this publication and its IP is unclear to the author. He originally envisioned it and has routinely updated it since. Another party, though, compensated him at least partially for the work. They did not commission it or assist with it in any other manner. No feedback has ever been given either.

One (hereinafter "Part One") is the funding mechanism needed to properly develop and deploy at scale DAC installations on a global basis.

Two (hereinafter "Part two") is the technical background information necessary to understand the scope and scale of the problem.

Three (hereinafter "Part Three") is the conceptual outline of this authors' technology meant to be used at scale for planetary engineering purposes. At scale means global deployment of the minimum number of installations (~$1e^3$) necessary to mitigate (separate, combust or fixate) atmospheric carbon dioxide and methane type contaminants on a sustained basis. Said basis would, through time, remove enough contaminants that air, oceanic and soils would recover to something approximating a safe steady state without impacting our global society and its current standard of living.

Four (hereinafter "Part Four") are the DACC notes with potential IP capture points that seem to be unique to this authors summary topic report and conceptual design.

Next, some other technologists use a term for at scale mitigation stated as “geoengineering”. This author prefers to use the term “planetary engineering” which avoids misinterpreting the sheer magnitude of an installation and the program needed to mitigate the issue.

In other words, planetary engineering is simply very large-scale engineering projects that are designed to support the resolution of problems caused by other infrastructure needs that support society. Put yet another way, planetary engineering is also the application of technology for the purpose of influencing the global environments of a planet.

Summarily, planetary engineering involves mitigating decreases in habitability on Earth. Point source industrial or municipal “treatment” is not planetary engineering scaled.

DACC needs to be conceptually designed, pilot tested, scaled and proven ASAP which means at scale installations beginning in the late 2030’s and with substantial completion by 2050.

PART ONE: THE FUNDING MECHANISM

Planetary scale infrastructure projects like Direct Air Carbon Capture (DACC) can be funded from a tax source that has never been exploited. This tax source can be exploited by any government:

Energy Consumption

Energy consumption is now tracked by the U.S. Energy Information Administration which is part of the U.S. Department of Energy. A few other countries track this as well.

Energy consumption is reported as units of “Btu consumed” and usually in blocks of 1000 Btu.

FUNDING MODEL

- An energy consumption tax would be collected in $0.01 / 1000 Btu “blocks” as they are “consumed” or similar.
- A carbon removal award would be paid in $5.00 / ton “blocks” as they are “removed” or similar.
- The energy consumption tax would equal roughly $10 Trillion / year if taken on a global basis.
- The carbon removal award would equal roughly $7 Trillion / year if taken on a global basis.
- The balance of these taxes and awards for energy savings could be spent on more mundane but necessary infrastructure uses such as roads, bridges etc.
- These taxes and awards would be collected daily from local / county / state and federal sources on a global basis.
- This tax “pool” would need to be protected from theft, money laundering, inflation or deflation or appropriation.
- Protection from these would require both cybersecurity and the tax pool funds converted to a “pool” of “coin”. A “coin” would be a unique cryptocurrency encrypted and protected by cybersecurity.
- Cybersecurity would be funded from the “pool”.
- Accruing the value of “coin” in the “pool” is important especially as energy consumption declines.
- Cryptocurrency for this "pool" would therefore have a finite or fixed number of "coins" available for distribution into qualified projects.
- Accepted and qualified projects would have "coins" converted to USD or other fiat monies to purchase goods and services for the "project".
- Incentives for demonstrable energy savings (some multiple ranging from small to large) would be offered and paid as incremental “coin” for projects that save "energy" both during construction and over its lifetime.
- Said incentives would be paid out both on an anticipated and incremental time basis.

WHY DO A FUNDING MODEL?

- Protection would need no oversight except cybercrime prevention.
- Coins increase in value as energy "savings" occur due to the limited number of coins.
- A small number of new coins can be created by “block chain mining” or as incentives realized for energy budget consumption reduction.
- The total value of the coin "pool" would accrue rapidly and likely exceed some very large $ amount in Yr1 let alone Yr10.
- A sovereign cryptocurrency avoids inflation or deflation risks, acts of God, money laundering, or theft risk etc. Trading between this cryptocurrency and others would be forbidden.
- A founder (whoever that turns out to be) keeps a set minimum number of coins. As coins are "added" or the pool value grows they can be converted to any fiat money either individually or as a block.

FUNDING USES

- Development of sufficient cybersecurity to ensure the integrity of the pool could be seen as infrastructure. This cybersecurity need not be limited to only uses pertaining to the pool.
- Energy transmission and its related infrastructure could be included or by extension it's cybersecurity and integrity.
- Water treatment and its distribution and food (although food would be a conceptual "stretch).
- Roads, bridges, dams, levees, traffic lights, toll booths etc would be funded.
- Also, nextgen data transmission networks (5G or later) could be funded and maybe should be funded since they seem to be "evergreen".

- Atmospheric carbon stripping via DACC and its permanent removal from the carbon cycle should be included as well. Runaway climate change will cause a global societal collapse far more readily than failing roads or telecommunications.
- This author proposes that planetary scale atmospheric carbon stripping and permanent removal by fixation is the most difficult topic to be considered or acted upon within an infrastructure development framework.

PART TWO: TECHNICAL BACKGROUND NOTES

A reasonable summary of the scale of atmospheric carbon in our atmosphere and why it must be removed as stated by others:

“Since the Industrial Revolution, humans have emitted more than 2,000 gigatons of carbon dioxide into the atmosphere. (A gigaton is one billion metric tons.)

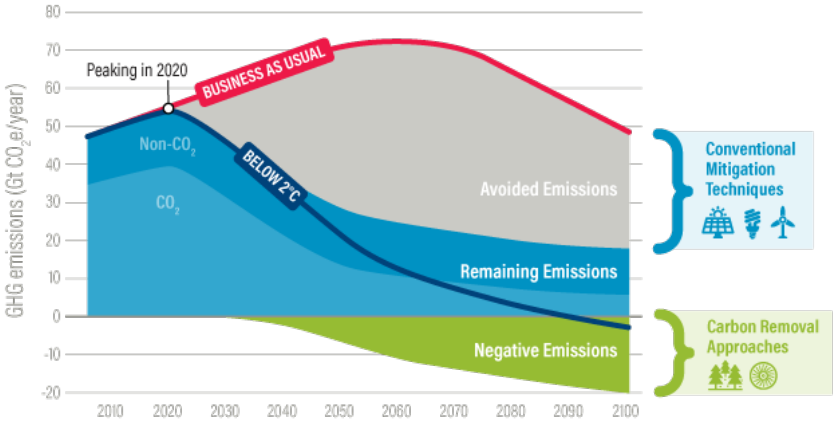
This thickening blanket of heat-trapping greenhouse gases is the cause of the global warming we are experiencing today. If nothing changes, climate impacts such as forest fires, stifling heat waves and damaging sea level rise will only continue to intensify.

The imperative for combatting climate change is to dramatically curb carbon emissions—for example, by ramping up renewable energy, boosting energy efficiency, halting deforestation, and curbing super pollutants like hydrofluorocarbons (HFCs). The latest climate science tells us, however, that these efforts alone aren’t enough to prevent dangerous climate change. To keep global temperature rise to less than 1.5-2 degrees C (2.7-3.6 degrees F), the limit scientists say is necessary for preventing the worst climate impacts, we’ll need to not only reduce emissions, but also remove and store some carbon from the atmosphere [4]. In fact, most climate scenarios show we’ll

need to remove billions of metric tons of carbon dioxide annually by midcentury, while also ramping up emissions reductions.

Carbon removal can take several forms, from new technologies to land management practices. The big question is whether these approaches can deliver carbon removal at the scale needed in the coming decades.

Staying Below 2 Degrees of Global Warming



Source: Adapted from UNEP 2016.
For more information, visit wri.org/carbonremoval.

WORLD RESOURCES INSTITUTE

Note: This is a notional scenario consistent with an at least 66 percent chance of limiting global warming to below 2°C. Some residual gross greenhouse gas emissions (both CO2 and non-CO2 such as CH4 or methane) will remain at the end of the century even with ambitious climate action because they are too difficult or costly to remove entirely. Once negative emissions exceed those that remain net zero emissions are reached. Faster and/or deeper emission reductions could reduce the role for carbon removal; slower and/or weaker emission reductions would increase the need for carbon removal."

This author: Forests and farmlands make for ready but very temporary removal of atmospheric carbon. Oceans offer the same temporary removal solution. A permanent solution would be the removal of atmospheric carbon on a very large scale and "fixing" the carbon (largely CO2 and methane) that removes it completely and permanently

from the carbon cycle. I do believe there is a viable and practical path to accomplishing that task. It's quite simple in concept – take the methane, concentrate it from the air and then combust it for power generation. Take both its combustion products (mostly CO2) and stripped atmospheric CO2 and fix it permanently by dissolving the CO2 in water and then allowing basalt (rock) to mineralize it in a permanent fashion as "limestone" or "dolomite". There is a way to do this – it's not new science. It's just never been done at this proposed scale before.

PART THREE: PLANETARY ENGINEERING DACC SOLUTION

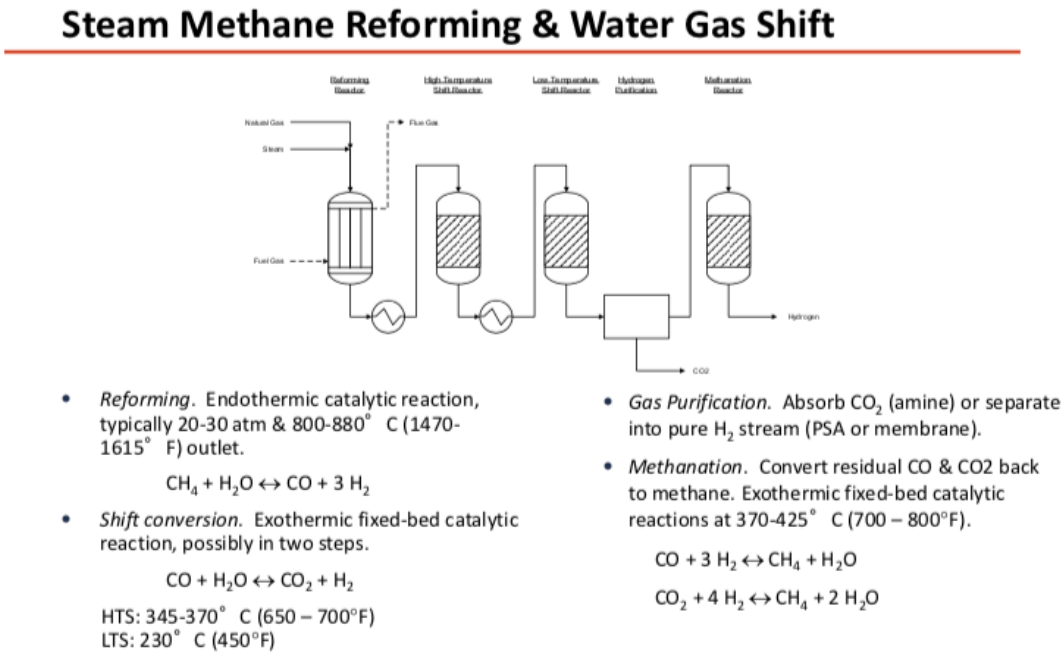
This process will take a lot of power to make it happen on any meaningful scale but will, in balance, with the other proposed renewable energy sources applied to it would be self-powered with a likely excess "dumped" to an external power grid. In all instances, any form of "emission" would be only water vapor. In all instances all processes are well proven. No new technology is required. But again, this removal process permanently removes, at a planetary scale atmospheric carbon, through potentially thousands of installations, using only renewable energy power and produces no pollution at all.

First, remove atmospheric water vapor in a series of large-scale venturi's which would collect and use the now condensed water for process needs or discharge its very large volume of fresh water to external sources. The venturis would have wind turbines mounted in their throats to provide a primary source of process power and to provide motive flow through the venturi's. No pollution at all.

Then take the molecular sieve separated methane and carbon dioxide, remove, and then concentrate them from the raw but now dried atmospheric influent. In an integrated methane reformer make concentrated hydrogen gas and a nicely separated

carbon dioxide gas stream suitable for compression, tank storage and subsequent deep well injection for permanent fixation as an insoluble carbonate rock mineral.

A description by others of a methane reformer is below:


Steam Methane Reforming & Water Gas Shift
Reforming Reactor
High Temperature Shift Reactor
Low Temperature Shift Reactor
Hydrogen Purification
Methanation Reactor
Natural Gas
Steam
Fuel Gas
Flue Gas
Hydrogen
CO2
• Reforming. Endothermic catalytic reaction, typically 20-30 atm & 800-880° C (1470-1615° F) outlet.
CH4 + H2O ↔ CO + 3 H2
• Shift conversion. Exothermic fixed-bed catalytic reaction, possibly in two steps.
CO + H2O ↔ CO2 + H2
HTS: 345-370° C (650 – 700°F)
LTS: 230° C (450°F)
• Gas Purification. Absorb CO2 (amine) or separate into pure H2 stream (PSA or membrane).
• Methanation. Convert residual CO & CO2 back to methane. Exothermic fixed-bed catalytic reactions at 370-425° C (700 – 800°F).
CO + 3 H2 ↔ CH4 + H2O
CO2 + 4 H2 ↔ CH4 + 2 H2O

The thus purified “filtrate” for the first molecular sieve (MS1) is blower transferred to a second molecular sieve (MS2) which separates nitrogen from the remaining atmospheric gases. Said nitrogen stream is then vented to atmosphere with no ill effect or by proper piping, valving and controls it is used to “strip” its molecular sieves of captured gases and return them to a ready state in a controlled manner.

The filtrate from MS2 would be an enriched or concentrated oxygen product suitable for compression, tank storage and then careful combustion as an accelerant with the methane reformer's compressed and tank stored enriched hydrogen product.

A parallel process but closely integrated air separation unit (ASU) would then cryogenically make liquid oxygen (LOX) and liquid nitrogen (LN2) with its excess vented harmlessly to the atmosphere with other process off gases such as excess to need oxygen and some very small amounts of NOx from the expanding gas turbine power generation plant.

As just previously mentioned the hydrogen and oxygen products would then be combusted in an expanding gas turbine spun to make power for use within the facility. Excess heat would be recaptured to optimize power generation or to help drive the heat exchange of another power source – geothermal power. No pollution at all.

The geothermal power process would most commonly be hot dry rock using as a heat transfer medium supercritical CO2 which when compressed and liquefied and pumped downhole on a recirculating basis would act as an effective heat exchange liquid. Some small volume of the liquid CO2 would react with the surrounding hot dry rock forming in-situ precipitate carbonates (permanent carbon removal). This power generation process produces nothing but water vapor. No pollution at all.

A simple sketch and associated text by others to explain this concept is below:

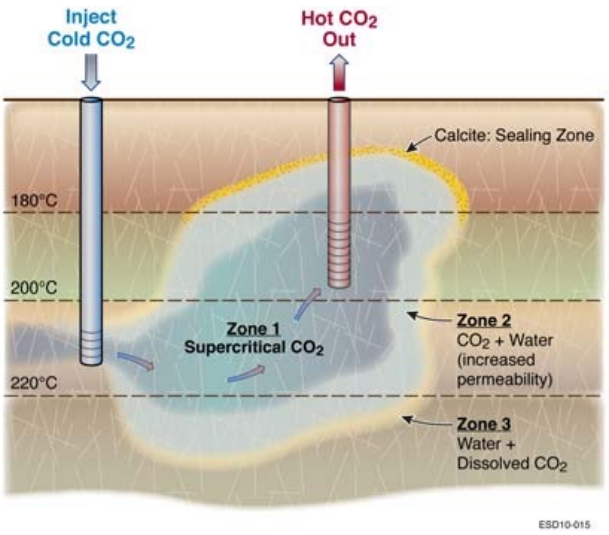
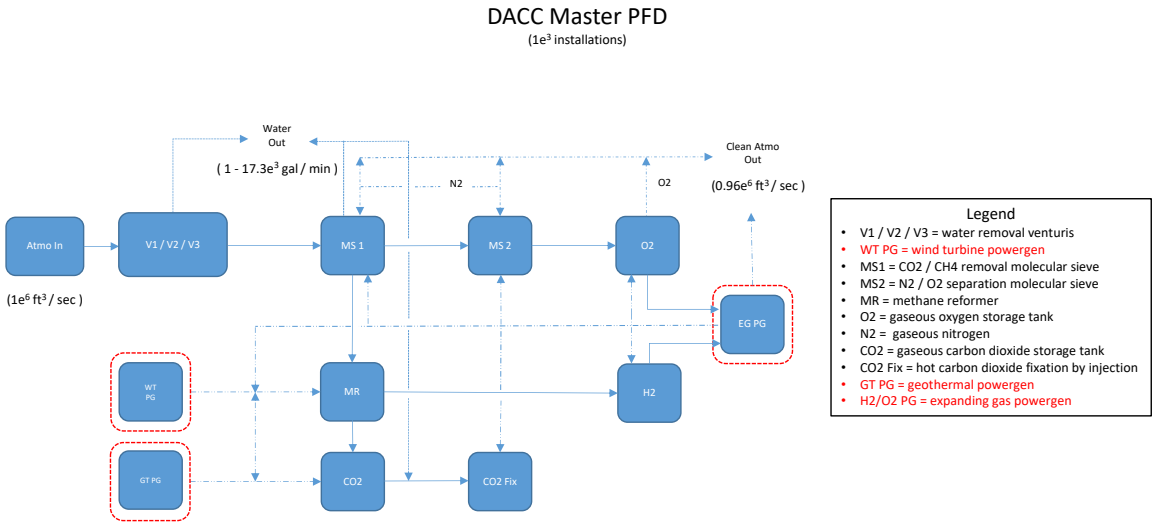


Figure 1. Schematic of the three zones created by injection of CO_2 into hot fractured rock (after Fouillac et al., 2004; Ueda et al., 2005).

"The peripheral zone (Zone 3) of an EGS operated with CO_2 may experience a combination of mineral dissolution and precipitation effects that could impact reservoir growth and longevity. The long-term behavior of this outermost zone will be crucial for sustaining energy recovery, for estimating CO_2 loss rates, and for figuring tradeoffs between power generation and geologic storage of CO_2. We have performed reactive geochemical transport simulations to study CO_2 induced mineral alteration in the outer zone, estimating associated changes in reservoir porosity, and sequestration of CO_2 by secondary carbonate precipitation."

Next, then take any other excess CO2 and fix it permanently by dissolving the CO2 in water (it can be seawater, freshwater, or highly contaminated groundwater btw) and then allowing basalt (rock) to mineralize it in a permanent fashion as "limestone" or "dolomite". There is a way to do this – again, it's not new science. But again, no pollution at all.

A simple master process flow diagram that captures all the above and was drafted solely by the author (major IP point) in late July 2019 is below:



A look at a modest but not scaleable first step that is being proven now by ClimeWorks (www.climeworks.com):

12.10.2017

At Climeworks, we are searching for solutions to unlock a negative emissions future. After years of hard work and research, we have developed a patented technology which is now in action at the world's first commercial Direct Air Capture (DAC) plant in Switzerland. Recently, we've been working on a different plant – and it's another world first…

We are excited to announce that we are combining safe and permanent geological storage with our highly scalable carbon removal technology through direct air capture of CO_2. The pilot plant is part of the CarbFix2 project which stores the air-captured CO_2 safely and permanently in basalt, leading us closer to our efforts to achieve global warming targets.

CarbFix2 has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 764760 and is led by Iceland's multi-utility company Reykjavik Energy. The collaborative research project centres around one of the world's largest geothermal power plants in Hellisheidi, Iceland, where CO_2 is currently injected and mineralized at an industrial scale.

Basalt core containing carbonates – Photo by Sandra O Snaebjornsdottir

PLANETARY ENGINEERING SCALED DACC NOTES WITH IP

- Climate change is beginning, and we are past the tipping point.
- Atmospheric carbon removal is crucial to slow or stop climate change.
- Industrial scale solutions cannot be scaled sufficiently to affect its major driver - atmospheric carbon accumulation and all its derivative issues.
- Terraforming is the most likely concept that grasps what must be done.
- Science fiction must become science fact with no chance of "do overs".
- Mission Impossible must be mission fact.
- No new science or physics, no new chemistry, no “unobtainium” allowed - we have no time.
- The Apollo program will be tinker toys in comparison.

- Where the money comes from is not my problem.
- Where the staff comes from is not my problem.
- Where the materials come from is not my problem.
- The concept, its design, operating conditions, and general locations are my problem.
- Design notes:
    - Page 12 process flow diagram is the property and discovery by and of this author (IP point).
    - Press / temp precip driven (50 bar and 100C) (IP point).
    - Block precipitation of carbonate (IP point).
    - Series atmo and precip process.
    - 70% venturi efficiency is OK if done in series as the venturi's are pictured (IP point).
    - Altitude placement critical – likely more than 2000 meters (IP point).
    - Syenite (basalt) location critical for carbonate precipitation.
    - RE sources critical
        - Wind
        - Geothermal
        - Lightning (harness the lightning and no pun) (IP point).
        - H2/O2 expanding gas turbine direct drive power generation.
    - Venturi effect for H2O and dust removal (think horiz scrubber).
    - Multi step venturi effect (IP point).
    - Materials of construction = CIP concrete (venturi throat mount - cross supports) of at least ACI 357 grade or better.
    - Controls for fixation = fe / mg or ca bleed through (IP point).
    - Controls for blending geothermal reinjection fluid with venturi or EGT condensate by conductivity and temperature (IP point).
    - Scale / sizing critical to ensure solution is effective should be done by others.
    - Stacked / nest inlets and outlets are acceptable.
    - Moving parts minimized:
        - Wind turbine(s) with winglets to avoid venturi erosion (IP point).
        - Pumps

        - H2/O2 expanding gas turbine and power generator
        - Molecular sieve indexing segmented disc
    - Planetary engineering scaled (never been done).
    - Lightning rods not required, domed CIP bronze caps and rings necessary constructed of C86300 (SAE 430B) alloy at minimum (IP point)
    - Water effluent for crop irrigation or potable consumption as determined by others as a 24/7 flow.
    - Locations ~ 1000's at a mean altitude of 8000' and oriented into a prevailing wind direction for optimal efficiency.
    - Venturi throats (which will likely be 100 meters wide or more) may be lined with "ridges" of an aspect to force sudden pressure drop to force water removal and drainage (IP point).
    - Venturi throats (in series) may be series heated / cooled for enhanced moisture removal (IP point).
    - Molecular sieve materials are known (BASF' Basolite C300 etc.) – use them.
    - Circular segmented "disc" sieves slowly revolving on a horizontal axis with magnetic bearings would make the separation (IP point).
    - Offgassing the "carbon" would be done on a segment-by-segment basis into the ASU or methane reformer as required (IP point).
    - Dissolution of the residual carbon dioxide would be done in a small portion of the water effluent collected from the venture throat(s) (IP point).
    - Saturated solutions of the dissolved "carbon" or carbon dioxide would be pumped through series plumbed "blocks" of finely ground basalt (syenite more likely) and thereby be precipitated under an appropriate temperature and pumped pressure (IP point).
    - Fully loaded blocks would be gravity drained then placed in underground storage (IP point).
    - Underground "C" storage can be backfilled basalt (syenite) ore body.
    - Underground "C" storage can be dry rock contact zone margin.
    - On-site milling of syenite is the most practical solution if possible.
    - Milling is a wear intensive operation and will require manual oversight and maintenance.

- If constructed properly and automated correctly the “system” would only require periodic and planned maintenance.
- Process details may be covered by other of this author’s publications.
- Other, simpler, process schema such as blower / absorbent and selective membrane technology are not scaleable for at scale planetary engineering purposes.
- Other, simpler, process schema is suitable for point source mitigation purposes such as industrial and municipal applications.

END